CHAPTER 7

COOLING SYSTEM

The intense heat generated when fuel and air are burned mandates that some means of cooling be provided for all internal combustion engines. Reciprocating engines are cooled either by passing air over fins attached to the cylinders or by passing a liquid coolant through jackets surrounding the cylinders. Cooling is made easier because combustion occurs only during every fourth stroke of a four-stroke-cycle engine. In contrast, the burning process in a gas turbine engine is continuous, and nearly all of the cooling air must pass through the inside of the engine. If enough air were admitted to the engine to provide an ideal air-fuel ratio of 151, internal temperatures would increase to more than 40000°F. In practice, a large amount of air exceeding of the ideal ratio is admitted to the engine. This large surplus of air cools the hot sections of the engine to acceptable temperatures ranging from 1100° to 1500°F.

COOLING OF ENGINE OUTER CASE

Figure 7-1 illustrates the approximate engine outer-case (skin) temperatures encountered in a properly cooled dual-axial compressor turbojet engine. Because of the effect of cooling, the temperatures of the outside of the case are considerably less than those encountered inside the engine. The hottest spot occurs opposite the entrance to the first stage of the turbine. Although the gases have begun to cool a little at this point, the conductivity of the metal in the case carries the heat directly to the outside skin.

COOLING OF COMBUSTION CHAMBER AND GAS PRODUCER

The air passing through the engine the combustion-chamber burner cans or liners. The cans are constructed to induce a thin, fast-moving film of air over both the inner and outer surfaces of the can or liner. Can-annular-type burners are frequently provided with a center tube to lead cooling air into the center of the burner to promote high combustion efficiency and rapid dilution of the hot combustion gases while minimizing pressure losses. In all types of gas turbines, large amounts of relatively cool air

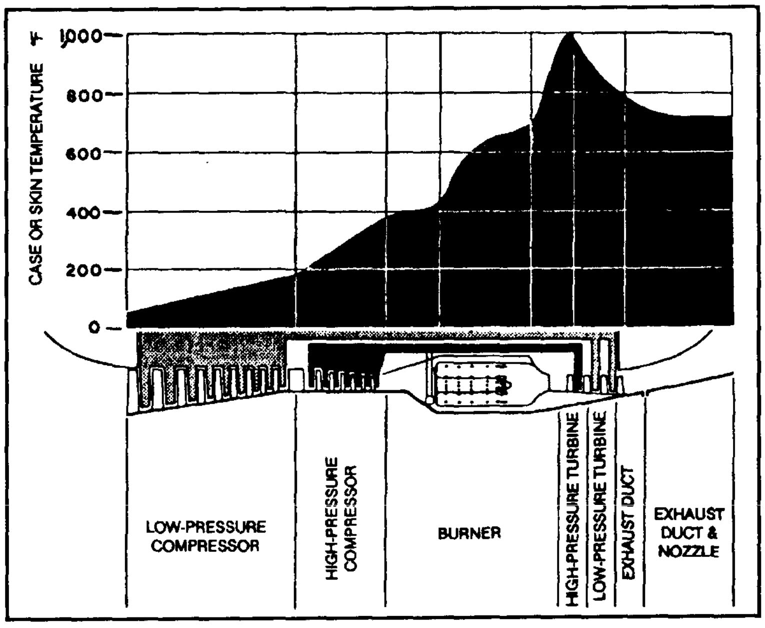

Figure 7-1. Typical Outer-Case Temperature for Dual-Axial Compressor Turbojet Engine

join and mix with the burned gases aft of the burners to cool the hot gases just before they enter the turbines.

All stage 1 and 2 airfoils in the GE T-701 engine are internally cooled by means of compressor discharge air (Figures 7-2, 7-3). The stage 1 nozzle leading edge is conection- and film-cooled with the air exiting through a shower-head series of holes in the leading edge. Aft of the leading edge, film-cooling air exits through convex and concave side gill holes and trailing edge slots. Cooling air for the stage 2 nozzle is bled from the centrifugal impeller exit and piped back through the midframe to enter the stage 2 nozzle. It cools by internal convection,

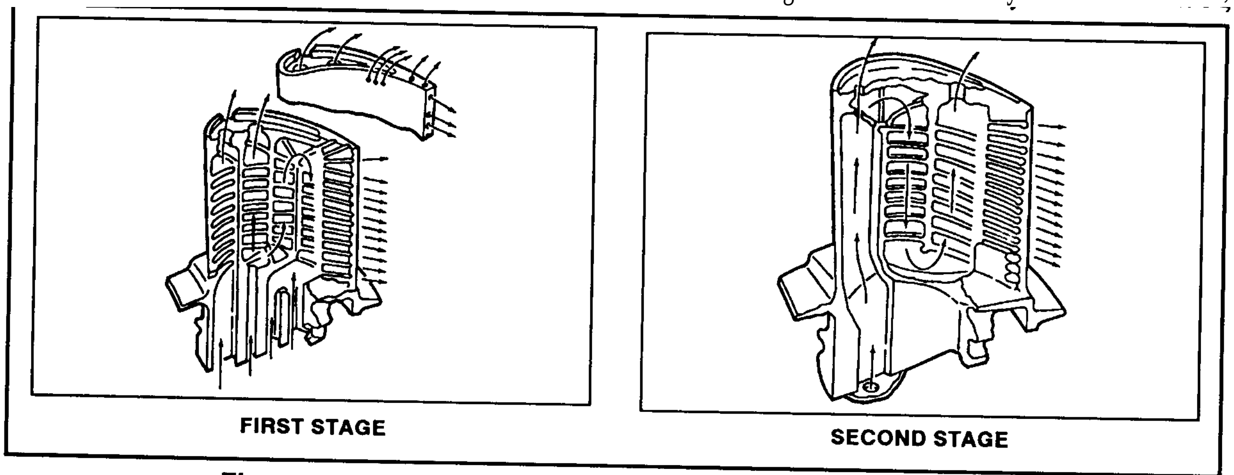

Figure 7-2. First- and Second-Stage Turbine Blade Cooling

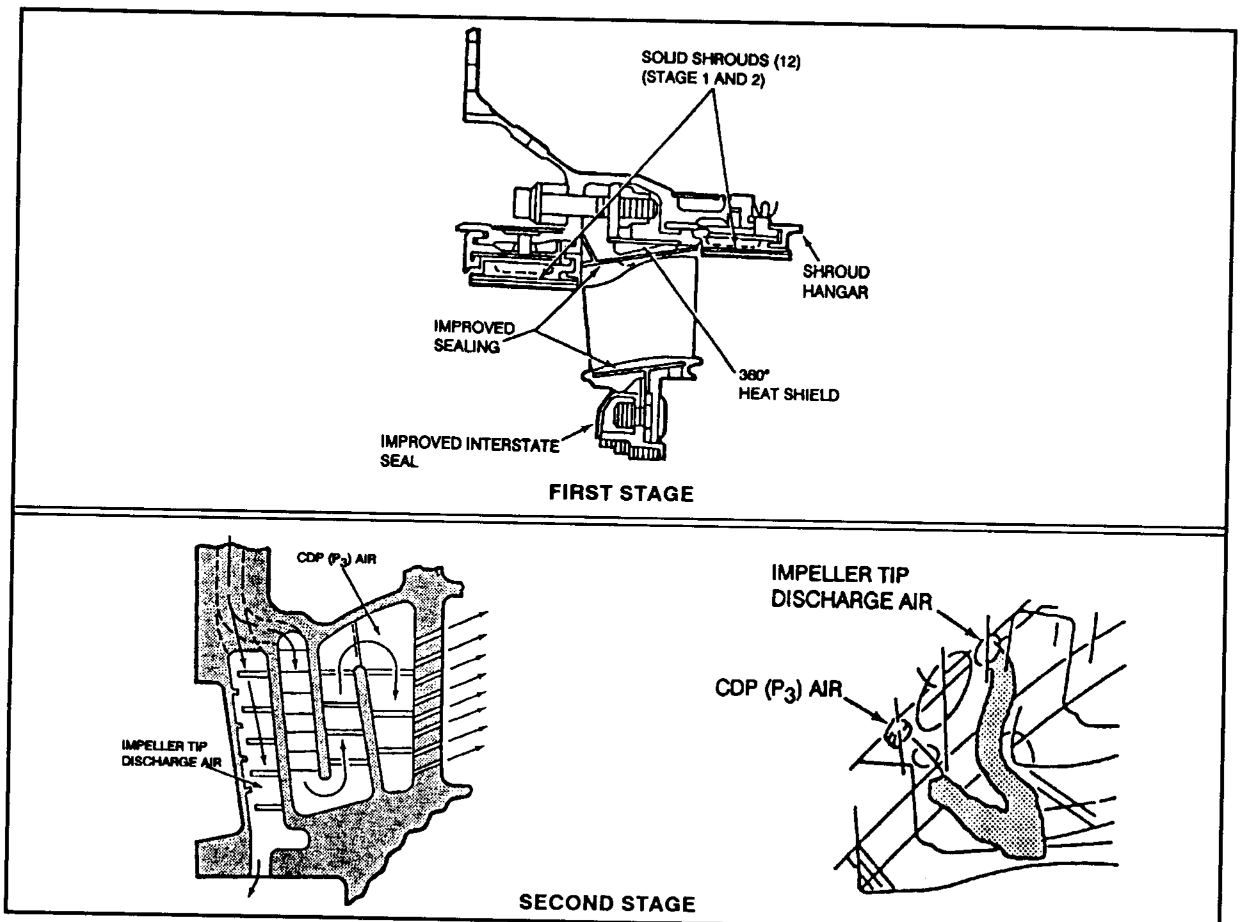

Figure 7-3. Nozzle Cooling

exiting both by trailing edge holes and by inner band holes. There, it cools the interstage seal. The turbine blades are convection-cooled through radial holes in the dovetail. Air exits through tip holes. The stage 1 blades also employ trailing edge holes for cooling.

EXTERNAL COOLING

Cooling air inlets are frequently provided around the exterior of the engine to permit entrance of air to cool the turbine case, the bearings, and the turbine nozzle (Figure 7-4). In some instances internal air is bled from the engine compressor section and is vented to the bearings and other parts of the engine. Air vented into or from the engine is ejected into the exhaust stream. When an accessory case is mounted at the front of the engine, it is cooled by inlet air. When located on the side of the engine, the case is cooled by outside air flowing around it.

The engine exterior and the engine nacelle are cooled by passing air between the case and the shell of the nacelle. The engine compartment frequently is divided into two sections. The forward section is built around the engine air inlet duct; the aft section is built around the engine. A fume-proof seal is provided between the two sections. The advantage of such an arrangement is that fumes from possible leaks in the fuel and oil lines contained in the forward section cannot become ignited by contact with the hot sections of the engine. In flight ram air provides ample cooling of the two compartments. On the ground air circulation is provided by the effect of reduced pressure at the rear of the engine compartment produced by gases flowing from the exhaust nozzle.

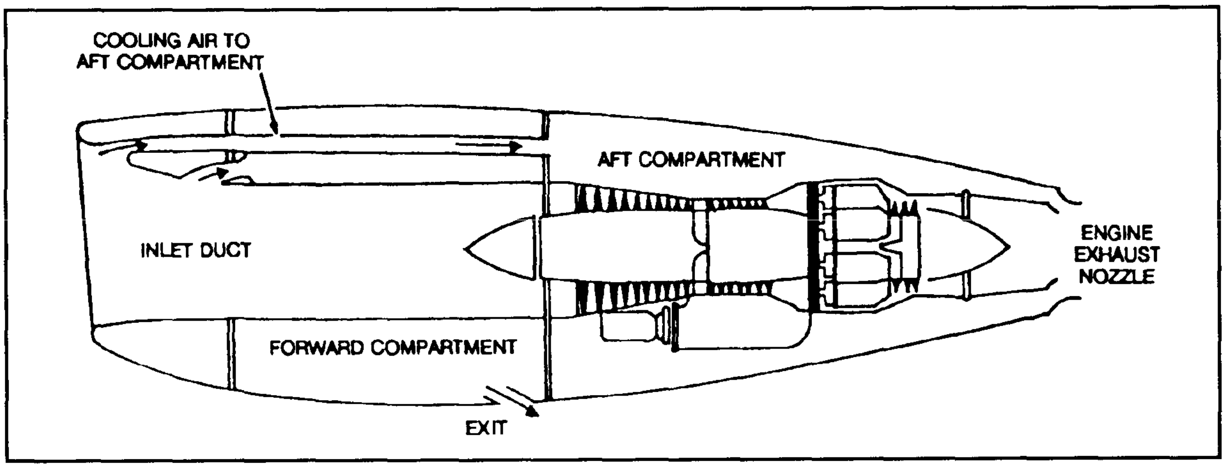

Figure 7-4. Typical Engine Nacelle Cooling Arrangement